Desktop Tools For Sustainable Design

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Architects and engineers often are looking for information on sustainable building materials, tools to evaluate the life-cycle environmental impact and tools to obtain a green building rating. An article in November 2004 provided an overview of the green building rating systems and discussed the various aspects of sustainable design. This article provides the desktop information sources and software tools available to help designers throughout the design process. Examples of knowledge bases for sustainable design technologies, software tools for feasibility study and performance evaluation, and green building rating tools are presented.

A trend is growing towards designing high-performance buildings with least environmental impact and providing highest level of occupant comfort. Sustainable design requires design professionals to be proficient with building systems interactions and consider environmental impacts of design decisions. The development of green building rating systems such as BREEAM (British Research Establishment Environmental Assessment Matrix) and LEED® (Leadership in Energy and Environment) have provided an objective basis for rating buildings and require designers to consider several aspects of design not addressed by building codes.

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Once a building developer or design team sets a project goal to develop a sustainable building or achieve certain level of green building rating, an integrated design approach is required from the earliest stages of the project to identify design strategies, select materials and technologies and evaluate whole building energy and environmental performance.[1]

ASHRAE members and design engineers involved in a sustainable design project often require information and tools beyond energy simulation software. This article presents a compilation of resources available to assist designers in the various stages and aspects of sustainable building design.

A large number of resources are available on the Internet for sustainable design. These range from online design manuals, case-study information, databases and software tools. A typical Internet search for sustainable building design tools identifies more than 700,000 documents containing some sort of reference to a sustainable building design tool. This overwhelming interest in sustainability makes it difficult for designers to identify the appropriate tools or information. For purposes of this article, the available resources are classified under the following categories:

- Knowledge-based tools;
- Performance evaluation tools; and
- Green building rating tools.

Knowledge-based tools typically are design manuals and information sources that designers can use as reference materials for design strategies, new technologies, material properties, cost data or case study information.

Performance evaluation tools include life-cycle impact assessment, new technology assessment tools used for selection of materials and technologies, analysis and simulation tools for calculating energy consumption, lighting and indoor environmental quality. These tools are used in the preliminary design stages and in the whole building performance evaluation process.

Finally, the green building rating tools are resources available to determine the performance requirements and level of green

Knowledge Base Name	Web Address
Green Building Primer	www.energybuilder.com/greenbld.htm
Greening Federal Facilities Guide	www.eere.energy.gov/femp/technologies/sustainable_greening.cfm
Guiding Principles of Sustainable Design	www.nps.gov/dsc/dsgncnstr/gpsd/
High Performance Building Guidelines (New York)	www.nyc.gov/html/ddc/html/ddcgreen/highperf.html
High Performance Green Building Guidelines (Pennsylvania)	www.gggc.state.pa.us/publictn/gbguides.html
Los Alamos (LANL) Sustainable Design Guide	www.eere.energy.gov/buildings/highperformance/lanl_sustainable_guide.html
Minnesota Sustainable Design Guide	www.sustainabledesignguide.umn.edu
Santa Monica Green Building Program	http://greenbuildings.santa-monica.org
Sustainable Design Resource Guide	www.aiacolorado.org/SDRG/home.htm
Sustainable Building Technical Manual	www.sustainable.doe.gov/pdf/sbt.pdf
Sustainable Building Toolkit (California)	www.ciwmb.ca.gov/GreenBuilding/Toolkit.htm
Sustainable Building Sourcebook	www.greenbuilder.com/sourcebook/
Whole Building Design Guide	www.wbdg.org

Table 1: Design guide knowledge bases with Web sites listed for various guides and tools.

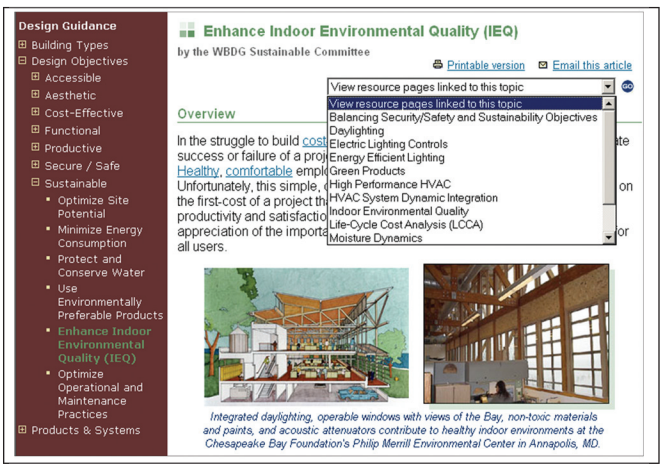


Figure 1: WBDG design strategy information for IEQ.

Name	Description	Web Address
Building Green Suite	Articles, Case Studies And Specifications By LEED Category	www.buildinggreen.com
High Performance Buildings	Case Studies Database	www.eere.energy.gov/buildings/highperformance/case_studies/
Green Matrix	General Design Information Resource	Available in CD from: www.ratcliffarch.com/green_architecture/green_arch.html
Green Building Advisor	Technology And Materials Selection Design Resource	www.greenbuildingadvisor.com/
Sustainable Building Information System	Information Resource For Tools, Technologies And Case Studies	www.sbis.info

Table 2: Searchable/interactive knowledge base.

building rating based on the rating methodology used. For each category, a few representative examples of tools are included in this article to illustrate the type of information and services available to designers.

Knowledge-Based Tools

Sustainable building design requires knowledge of systems integration and information on the technologies and environmental impact. Designers interested in learning about sustainable design principles can refer to books such as the recently published *ASHRAE GreenGuide*[2] or knowledge bases from any of the green building information Web sites listed in *Table 1*. The Web resources provided in these sites are well structured with design information and resources available for each of the sustainable design categories such as site selection, water and energy usage, construction materials selection and indoor environment.

Design guidelines provided in many of the Web sites in *Table 1* group the Web pages in a hierarchy similar to LEED credit categories[3] or broad topics of sustainable building design. The "Whole Building Design Guide" (WBDG) provides a matrix that links each LEED credit category to a number of WBDG articles available on-line. Each WBDG article provides a comprehensive summary of the design strategy and includes Web links to other related resources. *Figure 1* shows an example of information available for enhancing indoor environmental quality.

The knowledge bases of design guidelines in *Table 1* provide minimal search or interactive capabilities, requiring the designer to navigate through various pages for information. For more specific needs, several interactive and searchable knowledge bases with database links are available. Designers interested in considering a specific technology or LEED credit category can easily obtain information on related performance data, performance evaluation tools or case study descriptions. *Table 2* provides a sample list of such tools and types of information presently available. A brief description of each tool is given below:

- Building Green Suite of online tools provide an extensive collection of product information, articles from Environmental

Name	Description	Web Address
(i) Life Cycle Environmental Impact Assessment Tools		
ATHENA	Environmental Impact Estimator	www.athenasmi.ca
BEES	Building Environmental and Economic Sustainability	www.bfrl.nist.gov/oae/software/bees.html
ENVest	Environmental Impact Assessment and Whole Life Cost Analysis	http://envestv2.bre.co.uk
LISA-LCA	Life Cycle Assessment in Sustainable Architecture	www.lisa.au.com
(ii) Sustainable Technology Assessment Tools		
RETScreen	Clean Energy Project Analysis Software	www.retscreen.net
SkyCalc	Optimum Skylight Design Strategies for Lighting Energy Savings	www.energydesignresources.com/resource/129/
WATERGY	Water Savings and Potential Energy Savings	www.eere.energy.gov/femp/information/download_watergy.cfm
(iii) Simulation Tools for Energy and Indoor Environmental Assessment Tools		
DAYSIM	Dynamic Daylight Simulations	http://irc.nrc-cnrc.gc.ca/ie/light/daysim.html
CONTAM	Multizone Indoor Air Quality and Contamination Transport Analysis	www.bfrl.nist.gov/IAQanalysis/index.htm
Cx Asst.	Commissioning Assistant	www.energydesignresources.com/resource/176/
Green Building Studio	Energy Simulation and CAD Interoperability	www.greenbuildingstudio.com

Table 3: Performance evaluation tools used for the early stages of sustainable design.

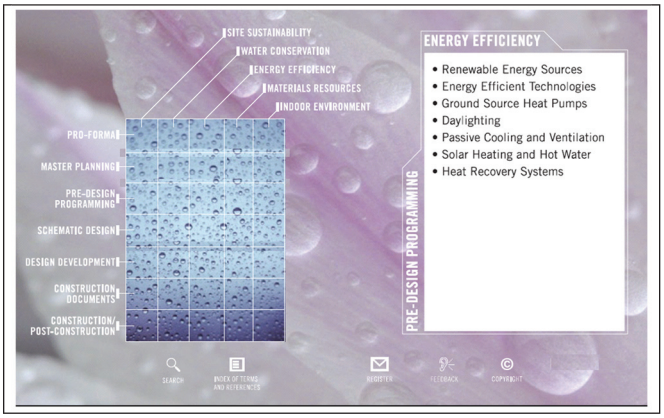


Figure 2: Design resource information from Green Matrix.

Figure 3: Design strategies from Green Building Advisor.

Building News, case studies and construction specifications searchable by LEED category and green topics.

• The High Performance Building Database is a growing collection of construction and performance details with more than 65 buildings at present. This database contains a powerful search capability to identify project information using keywords related to LEED rating and high performance buildings.

• Green Matrix is a design resource tool that links the topics of sustainability with the various stages of design with links to full-length articles and Web links. *Figure 2* shows an example of Green Matrix information for energy efficiency technologies that can be considered during the predesign programming stage. Each technology or design strategy has a dedicated information resource page with description and links. These resources were compiled by practicing architects to simplify the search for sustainable design strategies information.[4] The Green Matrix is somewhat similar to the WBDG matrix, with an extensive list of resources rather than link with specific design strategy articles.

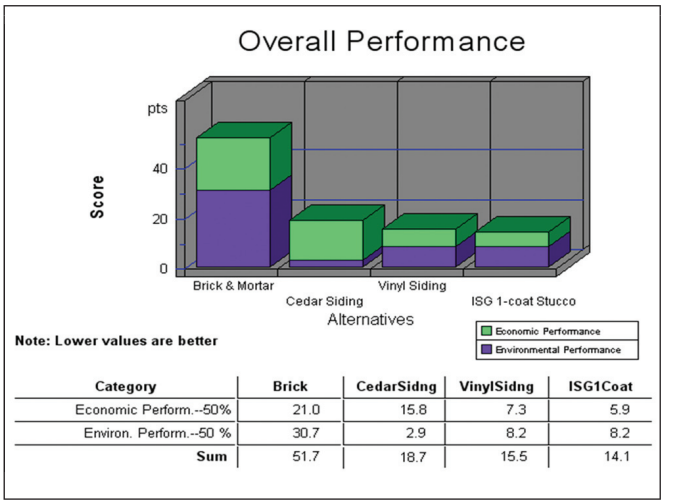
• The Green Building Advisor is a knowledge-based system with some built in intelligence to provide a qualitative assessment of a project and recommend sustainable design strategies. The knowledge base consists of about 750 sustainable design strategies, an extensive catalog of product information, a few case studies and technical articles. This system provides a simple graphical user interface and ranks the advice by sustainable design topics and building systems, making it easy for designers to identify the relevant information for their designs. *Figure 3* shows an example of design strategies suggested by Green Building Advisor for a typical commercial building project.

• The Sustainable Building Information System (SBIS) is a database containing more than 12,000 records of information related to technologies, technical papers, building details, software tools, rating programs and R&D projects for sustainable building design. SBIS includes a flexible user interface to search the database using green building topics and key words.

The knowledge-based design guides and searchable databases provide valuable information for designers considering sustainability or green building rating for their projects. These tools can save time in research and direct designers towards the appropriate technology or material selection often critical during the earliest stages of design.

Performance Evaluation Tools

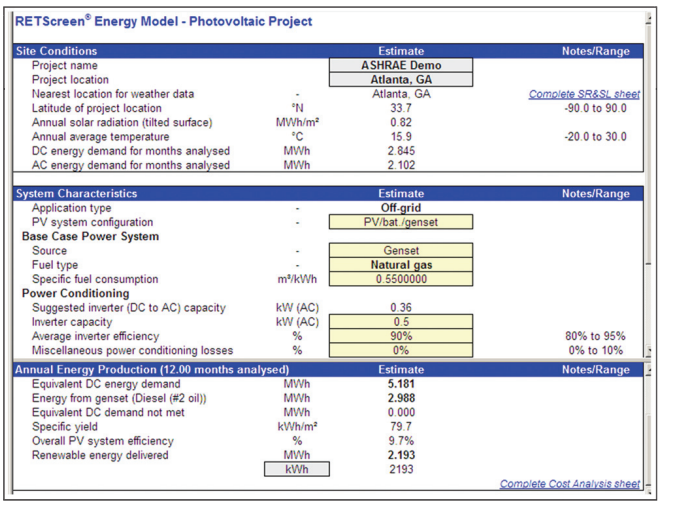
During the early stages of sustainable design, it is important to consider all possible design options and evaluate their life-



Note: Lower values are better

Category	Brick	CedarSidng	VinylSidng	ISG1Coat
Economic Perform.--50%	21.0	15.8	7.3	5.9
Environ. Perform.--50 %	30.7	2.9	8.2	8.2
Sum	51.7	18.7	15.5	14.1

Figure 4: BEES comparing exterior wall performance.



RETScreen® Energy Model - Photovoltaic Project

Site Conditions		Estimate	Notes/Range
Project name		ASHRAE Demo	
Project location		Atlanta, GA	
Nearest location for weather data	-	Atlanta, GA	Complete SR&SL sheet
Latitude of project location	°N	33.7	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	0.82	
Annual average temperature	°C	15.9	-20.0 to 30.0
DC energy demand for months analysed	MWh	2.845	
AC energy demand for months analysed	MWh	2.102	

System Characteristics		Estimate	Notes/Range
Application type	-	Off-grid	
PV system configuration	-	PV/bat./genset	
Base Case Power System			
Source	-	Genset	
Fuel type	-	Natural gas	
Specific fuel consumption	m³/kWh	0.5500000	
Power Conditioning			
Suggested inverter (DC to AC) capacity	kW (AC)	0.36	
Inverter capacity	kW (AC)	0.5	
Average inverter efficiency	%	90%	80% to 95%
Miscellaneous power conditioning losses	%	0%	0% to 10%

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Equivalent DC energy demand	MWh	5.181	
Energy from genset (Diesel (#2 oil))	MWh	2.988	
Equivalent DC demand not met	MWh	0.000	
Specific yield	kWh/m²	79.7	
Overall PV system efficiency	%	9.7%	
Renewable energy delivered	MWh	2.193	
	kWh	2193	

Complete Cost Analysis sheet

Figure 5: Photovoltaics analysis using RETscreen.

cycle impact. The information available during this preliminary design stage is limited and requires tools that can guide designers with default data and intelligence. Several different types of software tools are available depending on the nature of technology or design strategy being evaluated. Some of these tools can be used in the detailed design stages to evaluate whole building performance such as energy consumption and environmental quality. *Table 3* shows an example list of various types of software available for preliminary and detailed design stages. These tools fall into three major categories: (1) life-cycle environmental impact assessment tools; (2) sustainable technology assessment tools; and (3) simulation tools for energy and lighting performance evaluation.

• Life-Cycle Environmental Impact Assessment Tools: Sustainable design requires selection of environmentally friendly construction methods and materials. Recycling, reducing waste and minimizing the resources required to produce these materials are all critical for making design decisions. Several tools exist with databases to determine the cradle-to-grave energy use and environmental impact of construction materials and technologies.

Table 3 lists some of the well-known software tools developed in the United States (BEES), Canada (ATHENA), Europe (ENVest) and Australia (LISA). All of these tools require project information available in the early stages of design and provide options for comparing design alternatives. *Figure 4* shows sample output from BEES for comparing four exterior wall materials based on equal weighting of life-cycle energy environmental performance.

In BEES, the environmental impact assessment is based on raw material acquisition, manufacture, transportation, installation, use, and recycling and waste management; and the economical impact is calculated using the costs of initial investment, replacement, operation, maintenance and repair, and disposal.

• Sustainable Technology Assessment Tools: renewable energy and water conservation are important aspects of sustainable design. RETscreen, SkyCalc and WATERGY are some of the tools to evaluate and compare technologies for energy savings and water conservation. RETscreen can be used to evaluate energy production, life-cycle costs and greenhouse gas emission reductions for various types of energy efficient and renewable energy technologies such as photovoltaics, combined heat and power, wind energy, biomass and solar technologies. The RETscreen modules are spreadsheet applications integrated with an extensive product database and weather data.

Figure 5 shows an example worksheet of photovoltaic system energy model to estimate total energy production. Several additional worksheets are associated with this to determine green house gas emissions, life cycle costs and cost savings. SkyCalc and WATERGY are similar spreadsheet tools that can be used in designing skylights and selecting water-conserving fixtures.

• Simulation Tools for Energy and Indoor Environmental Performance: The DOE Building Energy Software Tools Directory (www.eere.energy.gov/buildings/tools_directory) provides a catalog of most of the hourly simulation programs for energy calculations. Designers could use any of the available hourly simulation software for obtaining LEED energy and atmosphere credits. The proposed building and the budget building according to ANSI/ASHRAE/IESNA Standard 90.1-1999/2001, *Energy Standard for Buildings Except Low-Rise Residential Buildings* need to be modeled and the energy performance needs to be documented for claiming these credits. Some of the widely known tools include EnergyPlus, DOE 2.1E, BLAST, Energy-10, eQuest, or DOE 2.1E based tools with user-interfaces such as PowerDOE, Visual DOE and EnergyPro.

More recently, CAD to energy simulation software interoperability is provided by the Green Building Studio Web service, which enables designers to evaluate energy performance at early stages of design and assist with product selection. In addition to energy simulation, software tools are available for daylight simulation using DAYSIM and indoor pollutant migration analysis using CONTAM. These tools may be needed during the design process, but may not be needed for LEED documentation, unlike the energy simulation software output.

In addition, several software tools are available for water conservation calculations, materials emissions calculations, daylighting simulations, building commissioning plan devel-

Name	Description	Web Address
LEED Calculator	Spreadsheet Tool Included as Part Of LEED V2.0 Reference Package	www.usgbc.org/LEED/publications.asp
BREEAM Assessment Prediction Checklist	PDF Documents Used As Pre-assessment Design Checklists	http://products.bre.co.uk/breeam/offices.html
GBTool	Green Building Challenge Assessment Framework	http://iisbe.org/iisbe/gbc2k5/gbc2k5-dwn.htm
ABGR	Australian Green Star Rating Tool	www.abgr.com.au/java/calc_applet.html

Table 4: Various rating systems and tools.

opment and other aspects of sustainable design. Some of the knowledge-based tools such as GreenMatrix and SBIS provide detailed information and links to identify these other performance assessment tools.

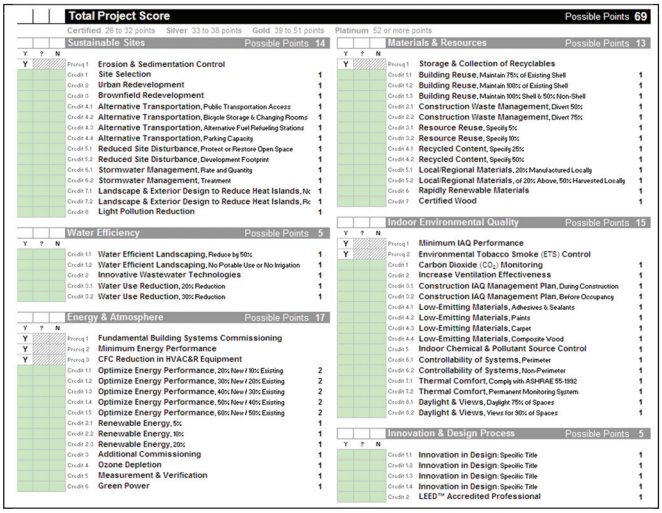


Figure 6: LEED calculator summary worksheet.

Green Building Rating Tools

Each green building rating system provides a matrix or a spreadsheet to assist designers in identifying design criteria, document proposed design performance and calculate the number of credits that can be obtained towards overall rating. *Table 4* shows the various rating systems and tools presently available. Most of these tools are spreadsheets primarily used as design checklists and rating credit calculators. These tools are different from knowledge-based tools, which provide assistance to the designer in selection of materials and design strategies for integrated building design.

LEED and GBTool provide some calculations embedded in the spreadsheets to determine the baseline performance requirements for calculating the rating points for energy conservation, water conservation, material reuse and emissions. *Figure 6* shows the LEED calculator summary worksheet for tabulating the credit points. This spreadsheet is useful for designers to identify the prerequisites, credit points obtainable and calculate the possible overall rating.

GBTool offers similar spreadsheets for self assessment, taking into account regional or local variations. GBTool is a research and development effort and does not offer any certification similar to LEED. The BREEAM assessments are carried out by certified assessors, but the pre-assessment checklists can be used by designers to identify and address requirements in the design process.

All the tools available from the rating programs are intended only for documentation and integrated assessment at the overall project level. To perform these assessments, baseline and actual building performance for energy consumption, embodied energy and other performance levels need to be determined using analysis and design tools.

Conclusions

A wealth of information and tools are available to assist designers in incorporating sustainable technologies and design strategies in their projects. This article presents a classification of software tools and several examples that are easily accessible on the Web, but does not cover all available tools or all aspects of sustainable building performance.

Most of the knowledge-based tools provide general design information, but are not adequate for feasibility analysis needed during the design process. The performance evaluation tools are useful for technology selection during preliminary design and could also be used in the detailed design stage to estimate design performance. The green building rating tools can be used to set sustainability design goals based on the overall certification level to be achieved and baseline performance targets; and for documenting the design performance. Designers entering the sustainability arena should select an appropriate rating tool and a knowledge-based tool to understand the requirements and identify design strategies. Then use the performance evaluation tools as the project progresses to feasibility and detailed design stages. Designers can use the sample knowledge-based tool links presented here as starting points to explore the available information and identify other performance assessment tools needed for their projects.

References

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